Impacts and Responses: Goods Movement After the Northridge Earthquake

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ABSTRACT

The 1994 Northridge earthquake disrupted goods movement on four major highway routes in Southern California. This paper examines the impacts of the earthquake on Los Angeles County trucking firms, and finds that the impact was initially widespread but relatively short-lived. Congestion delay and circuitous routing were the most common impacts. Rerouting and rescheduling strategies were ad hoc, rather than part of prearranged earthquake responses. The financial impacts of the earthquake were modest: mean first quarter revenues declined 0.2% while mean first quarter costs increased 3.5%. These impacts were smaller than expected because of quick restoration of highway access, made possible by redundancy in the road network and quick action by public agencies.

INTRODUCTION

The 1994 Northridge earthquake destroyed key highway infrastructure in Southern California. The magnitude of the damage and the dramatic initial disruption led many to expect significant, continu-

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ing operational and financial impacts on goods movement in the region (see map on page iv). This research uses a telephone survey of Los Angeles County trucking firms to explore responses to the disruption and to measure the financial impacts that trucking firms experienced over the first two quarters of 1994. It includes data from two California Department of Transportation (Caltrans) commissioned studies of responses to the earthquake: a telephone survey of dispatchers at Los Angeles County trucking companies (CIC Research Inc. 1994); and an intercept survey of trucking companies that asked about delay and rerouting activities (AMPG 1994).

MEASURING EARTHQUAKE DISRUPTIONS

There are numerous studies of earthquake disruptions (National Research Council 1992; Applied Technology Council 1991), but few of these look at disruptions to goods movement at the trucking-industry level. The only comparable study found in the literature is an examination of the goods movement impacts of the Loma Prieta earthquake in the San Francisco Bay area (Hansen and Sutter 1990). Such examinations are crucial, because efficient goods movement is essential to the nation's trade-oriented economy (Caltrans 1994).

Many factors determine how earthquakes affect goods movement. The extent of the impact depends on the magnitude of the earthquake, its location, geologic factors, the strength of highway facilities and buildings, and the responses of trucking companies and public agencies. Trucking firms must develop routing and scheduling strategies on almost an hourly basis, so their resourcefulness is important. That resourcefulness, however, depends in part on efficient public sector provision of information, workable detours, and ultimately, rebuilt facilities. Furthermore, business disruption among trucking firms' customers, which may have nothing to do with goods movement, influences the demand for goods movement after an earthquake.

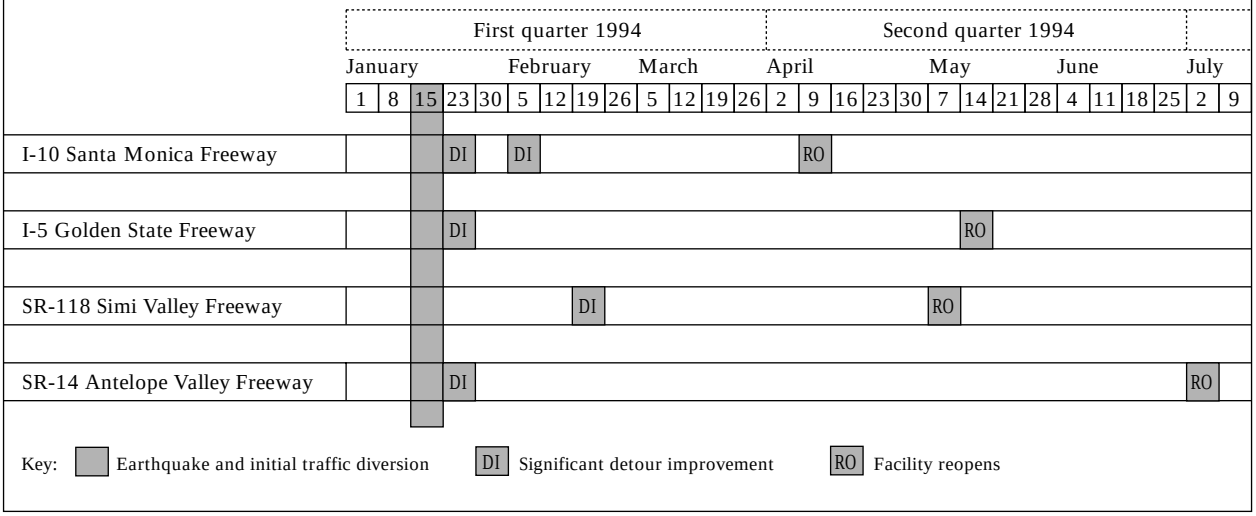
The type of transportation network affected is also a significant factor. A disruption to a hierarchical branching network is more disruptive than a similar impact on a network with many parallel routes and closed circuits. The Northridge earthquake illustrates the disruption of key trucking routes where suitable short-term parallel routes could be utilized. Moreover, the earthquake did not cause serious disruption to marine, air, rail, or pipeline goods movement.[1] The "bottom line" reported here, therefore, represents a complex amalgam of factors that is unlikely to be duplicated in the same combination in possible future earthquakes. This underscores the need for data on disaster impacts, so that a wide range of circumstances are represented.

Public officials moved quickly to restore transportation services after the earthquake. The initial responses were to plan and publicize detours. Then, better detours were made available on a gradual basis, and finally reconstructed facilities were opened at various times during 1994. As a result, the level of disruption changed rapidly. For example, the initial detour for the Golden State Freeway (I-5) was a circuitous route using the 101 Freeway, but during the first few weeks, closer-in detours were developed and used. Eleven days after the earthquake, the I-5 "Old Road" detour was created and trucking "appeared to return to almost exactly its pre-earthquake patterns"(AMPG 1994, 150). A similar pattern of responses occurred at each of the disrupted sections of freeway as detours and reconstruction occurred. Figure 1 provides a timeline of the restoration of transportation capacity in the key affected corridors.

The freeway system is an important component of the multimodal goods movement network that serves local business, intra- and interstate commerce, and international trade. The earthquake primarily had a disruptive effect on intraurban and intrastate truck-based goods movement involving agricultural products, household goods, and heavy specialized equipment (AMPG 1994, 18). Using the I-5 as an example, the most frequent origin/destination pairs for truck trips were central and east Los Angeles, Kern County, and other California

[1] Disruption to other modes was screened through telephone interviews and a review of government documents. The following disruptions were identified: Port of Los Angeles—one ship was redirected, but otherwise had normal operations; no disruption at Los Angeles International Airport; Southern Pacific Railway—the Northridge line was out of service for 48 hours because of a derailment; one crude oil pipeline (San Joaquin Valley Line 1) was out of service for over 3 months.

FIGURE 1 Time Sequence for Reopening Damaged Freeway Segments



counties to the north; less than 5% of the destinations and origins were outside California (AMPG 1994, 19).

METHODOLOGY

The research design is built around two objectives: measuring impacts and understanding the process of responding to the earthquake. The main research instrument is a survey of Los Angeles County trucking companies (hereafter referred to as the Cal Poly Pomona (CPP) survey), conducted during July/August 1994. Because so little comparative data are available on trucking industry responses to earthquakes, a goal of the research design was to increase opportunities for comparison with the small number of studies available.

Natural disasters pose special challenges to researchers. They require collaboration and ad hoc arrangements between organizations and agencies that do not usually work together. In this case, Caltrans almost immediately contracted with consultants to monitor and analyze the disruptions to the transportation system. This occurred before the academic research programs were initiated, and it presented opportunities to link the consultant and academic research efforts.

The first step in this project was reviewing the consultant surveys, particularly the CIC Research survey (hereafter referred to as the CIC survey), and surveys on this subject in other areas such as the Loma Prieta earthquake study by Hansen and Sutter (1990). These two projects are linked, since Caltrans requested that the CIC survey use similar questions as the Hansen and Sutter survey.

CIC and Hansen and Sutter surveyed dispatchers at trucking firms, asking about the following: exposure to damaged facilities, impacts on operations, responses to disruptions, and cost impacts. CIC Research purchased a list of Los Angeles County shippers and companies from a commercial provider. They drew a random sample from this list, stratified into two groups: trucking and manufacturing (80%); and wholesale, retail, and direct mail (20%). They contacted 847 firms and completed 300 telephone survey questionnaires. They received a low response on the surveys of the wholesale, retail, and direct mail group, often because the respondent had no trucks or did not use the freeway system. The surveys were conducted between May 23, 1994 and June 1, 1994.

The CIC survey provided good data on impacts and responses, by disrupted facility. However, the questions concerning financial impacts were ambiguous, and no information was collected on earthquake preparedness. Given this situation, the most productive approach for the CPP survey was to resurvey the firms responding to the CIC survey, asking the Chief Executive Officer (CEO) or Chief Financial Officer (CFO) about financial impacts and earthquake preparedness. The sample was

narrowed to the trucking firms in the CIC survey (Standard Industrial Classification (SIC) 42) for which a good sample size (n=269) was available.

The key issues in survey design concerned the best way to measure impacts and to obtain sensitive financial information. Financial performance during a pre-earthquake period is not a reliable measure, because many factors affect a business's costs and revenues, such as seasonal fluctuations and changes in the regional economy. Instead, respondents were asked to compare actual financial performance with that which they expected if the earthquake had not occurred. The results, therefore, represent the best judgment of CEOs and CFOs.

Options for the survey instrument included case studies, telephone surveys (Gordon and Richardson 1995; Hansen and Sutter 1990), and mail-back surveys (Boarnet 1998; Lockheed Information Management Services Company 1993). Two approaches were used in this study: a telephone survey of CEOs or CFOs; and a followup financial worksheet that was faxed to the respondent at the end of the telephone interview (to be mailed or faxed back). The attempt to collect detailed financial information with the "fax-back" form was unsuccessful. Despite numerous call-backs, firms were unwilling to return the financial worksheet because of confidentiality concerns and the time and effort to provide the information. However, respondents did estimate percentage changes in costs and revenues, and indicated the major components of the cost and revenue change during the telephone interview.

The CPP telephone survey included 25 questions about cost and revenue impacts, response strategies, earthquake preparedness, and firm characteristics. These questions built off the CIC survey. The sample frame for the survey was the CIC survey respondents, because linkages were sought between the CIC data and the CPP data.

The CPP survey sought at least 115 responses to estimate cost and revenue impacts within 2% (using the standard deviation found by Hansen and Sutter and a 95% confidence interval). A 62% response rate (of the CIC respondents) was achieved—164 telephone surveys were completed—exceeding the target sample size. These responses represent 8% of the trucking firms in the Los Angeles/Long Beach primary metropolitan statistical area (PMSA).

The CPP survey focused on the three SICs that are direct trucking operations: SIC 4212 "local trucking w/o storage" (hereafter referred to as couriers); SIC 4213 "trucking, except local" (hereafter referred to as intra- and interstate trucking); and SIC 4214 "local trucking w/ storage" (hereafter referred to as movers). The 116 completed intra- and interstate trucking interviews represent 19% of such firms in the Los Angeles/Long Beach PSMA (U.S. Department of Commerce 1990). Twenty-seven responses from couriers represent 2% of the population, and the 21 responses from movers represent 7% of the population. Poor representation in these latter categories stems from low response on the CIC questionnaire. Responses from those last two categories should be interpreted as exploratory. The sample was not stratified, because of concerns that questions about sensitive financial information might reduce response rates. CPP surveyors contacted all 269 firms that responded to the CIC survey.

The CIC and CPP databases were merged so that relationships between variables in each survey could be explored. Chi square tests were used to examine differences between categorical variables, t tests were used for differences in means, and Kendall's tau rank correlations were used for ordinal data.

Finally, comparisons were made with the results of Hansen and Sutter's study of the Loma Prieta earthquake. That study was based on a random sample from a list of 327 members of the California Trucking Association (CTA). Of 67 initial telephone contacts, 37 surveys were completed. The small sample size, the potential bias stemming from the CTA-provided list, and the inability to distinguish between types of trucking firms means that comparisons drawn later in the paper should be viewed as exploratory. However, such exploratory comparisons are justified because of the paucity of data in this area.

IMPACTS ON TRUCKING OPERATIONS

Trucking companies in Los Angeles County faced varying degrees of exposure to the damaged facilities, depending on the frequency with which they normally used those facilities. The CIC survey asked about the frequency of use of the affected routes before the earthquake. Respondents answered "no use," or one of four quartiles. Figure 2 shows that three-quarters of the respondents said that at least some of their routes used the I-10 or the I-5. Fewer than half the respondents said that at least some of their routes used State Route 14 (SR-14) or SR-118.

A composite measure of exposure to damaged facilities (EXPOSURE) was created using the midpoint values of four answer categories described above, and calculating the average response for the I-5, the I-10, SR-118, and SR-14. Calculating the mean EXPOSURE by type of trucking firm revealed no significant differences. Couriers, intra- and interstate trucking companies, and movers were exposed to disrupted facilities in about equal proportions.

The CIC survey asked an overall question about the types of impacts, offering respondents eight answer categories. Figure 3 summarizes the five most important impacts, showing the percentage responding that they experienced "moderate" and "severe" impacts. CIC surveyors did not define "moderate" and "severe" to respondents, so the most unambiguous interpretation is that grouping "moderate" and "severe" indicates a significant impact. Congestion delays and circuitous routing were reported by many respondents as they dealt with rerouting and detours around damaged facilities. Overloaded telephone lines hampered communication and planning, and dispatching was inefficient. Some trucking firms *gained* customers, as there was a need to transfer or deliver goods so that their customers could resume operations. Not shown are the less frequent responses: 15% of respondents lost customers, and only 7% of respondents had equipment damage.

FIGURE 2 Proportion of Runs Using Damaged Freeways

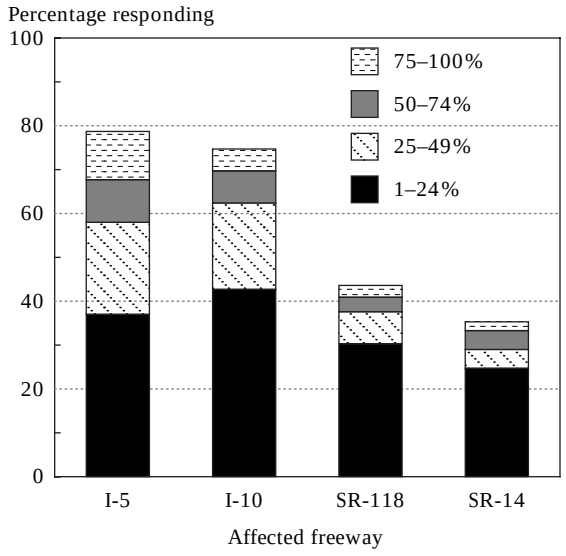
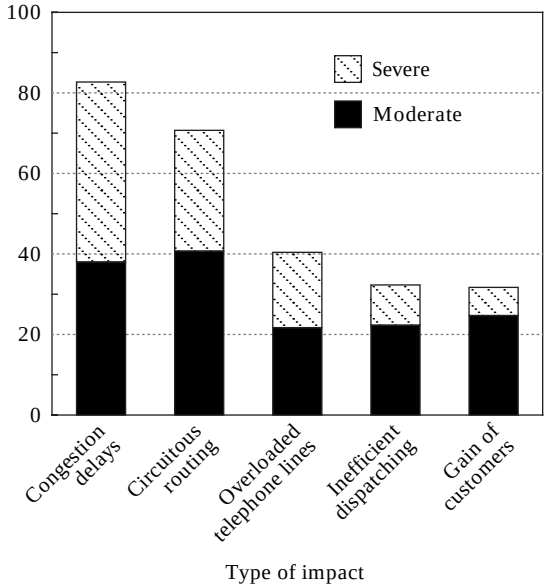


FIGURE 3 Impact on Trucking Operations



One would expect that greater exposure to damaged freeways would lead to greater reported impacts. A composite measure of impacts (IMPACT) was developed, assigning a weight of "1" to little or none, "2" to moderate, and "3" to severe in each category of impact, and then summing the values for each impact category. The combined measure of impacts excludes the "gain in customers" response. A Kendall's tau rank order correlation between EXPOSURE and IMPACT confirmed this positive relationship ($r=.23$, $p<.05$). We calculated IMPACT by SIC to see if

there were significant differences in impact, but found none (@ $p<.05$).

To test for a spatial relationship between location of the firm and impact, we segmented the data by geographic areas subject to the strongest ground shaking. Maps provided by the State Office of Emergency Services show areas subject to Modified Mercalli Index (MMI) VIII, IX, and X, which in total comprise 21 zip codes and 33 CIC survey respondents. We constructed a measure called SHAKE, which assigned a value of "3" to MMI X, "2" to MMI IX, "1" to MMI VIII, and "0" to all other areas. The +0.04 rank correlation between SHAKE and IMPACT suggests a positive relationship between ground shaking and impact, but is not statistically significant (@ $p<.05$). Proximity to ground shaking is not a significant explanatory factor, because of the weak connection between trucking firm location and the routes used by those firms.

The CPP survey asked about levels of absenteeism immediately after the earthquake. One-quarter of the respondents experienced increased absenteeism in the first week after the earthquake; the average absenteeism rate was 5.7%. The average absenteeism rate declined to 1.5% the second week; only 10% of the respondents experienced increased absenteeism. Despite these relatively low rates of absenteeism, trucking companies had the greatest need to develop contingency strategies during the highest absenteeism period.

The CIC survey asked about actions taken by trucking firms in response to the earthquake for each of the affected freeways. Figure 4 summarizes those impacts, averaging responses for all freeways. Combining the responses might seem to ignore important variation in actions among affected freeways, but a chi square test showed that there were no statistically significant differences between freeways. (See CIC Research Inc. 1994 for a detailed breakdown.)

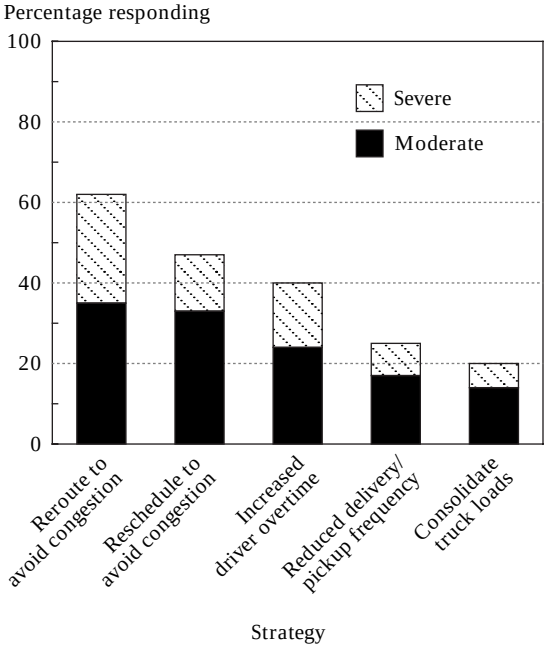
Most of the measures used were short-term responses, including rerouting, rescheduling (commonly starting earlier or delaying deliveries), increased overtime, reduced delivery/pickup, and consolidation of loads. There was little use of longer term strategies, such as using alternative rail or air modes. Respondents said that most of these actions (96%) were no longer being used by mid-May when the CPP survey took place.

CIC survey responses rated the acceptability of the primary detour for each of the damaged freeway segments they used. They overwhelmingly rated them as acceptable. Responses of "acceptable" ranged from 80% to 89% depending on the freeway, and the highest frequency of an "unacceptable" rating was 4%.

PLANNING, COMMUNICATIONS, AND COLLABORATION

Most trucking companies did not have an earthquake response plan in effect prior to the earthquake, nor did it stimulate them to prepare one. Of the 23% of CPP respondents that did have a plan, the dominant form was an emergency preparedness plan for employees, not an operational plan. Only a handful of respondents had a rerouting plan, a communications plan, an operations management plan, or arrangements with customers. Some respondents commented that the earthquake was one of a host of external factors that affected their business—other examples include the Los Angeles civil disturbance, a 1994 Teamster's strike, and economic restructuring. Earthquake prepared-

FIGURE 4 Response Strategies



ness, therefore, had not garnered substantial management interest in contingency and preparedness planning. On the other hand, these firms have operational experience under unforeseen circumstances, and therefore may be better equipped to cope with disruption.

The earthquake required firms to engage in a broad planning and management effort to respond to employee absenteeism, to coordinate deliveries with customers, and to plan rerouting and rescheduling. One-third of the respondents to the CPP survey changed their operations in response to the earthquake. There were significant differences in the frequency with which firms changed their operations—couriers did so most frequently (52%), followed by intra- and interstate truckers (36%), and movers (19%). Couriers may have changed their routes more often because of their complex set of locally based origins and destinations, and may have been more affected by highway disruption and short-term business closures.

As described previously, the primary activity was rerouting. Among those firms that rerouted, there was an even split between those who let drivers decide on new routes versus those who had dispatchers establish them. Few firms (less than 5%) reported having to reassign employees or create special teams or task forces. The couriers that reported greater operations changes were more likely to create special task forces, and more likely to let the driver select detour routes.

Trucking firms' greatest initial need was information that would enable them to develop rerouting and response plans. The most common information sources used were radio and television; newspapers ranked fourth. The most frequently used specialized information source was the California Highway Information Network, which ranked third. The use of nontrucking information sources was common, because the media was saturated with coverage of earthquake information, and apparently these sources were useful to trucking operations. Table 1 summarizes the most frequent sources of information. Respondents ranked the importance of these information sources, but assigning weights to the responses did not change their order. Weighting did reinforce the importance of commercial radio and television as the primary information sources.

TABLE 1 Responses to Survey Question: What information sources did you use to determine how to respond to the earthquake? (multiple responses permitted)

Frequency of responses	Unweighted (number of responses)
Highest	Commercial radio (85)
Second highest	Commercial television (36)
Third highest	California Highway Information Network (35)
Fourth highest	Newspapers (20)
Fifth highest	Other truckers (19)
Sixth highest	Contacts at California Highway Patrol (10)
Seventh highest	Customers (5)
Eighth highest	California Trucking Association telephone/fax(5)

Slightly more than one-third of respondents had communications problems after the earthquake. The median time of disruption was one day and the mean time was three days. Virtually all of the disruption was to telephone lines—a few respondents reported power and CB radio outages. The rapid resumption of telephone and fax capabilities may have made unnecessary the extensive use of other communications technologies. Other communications strategies used by Caltrans, such as changeable message signs, were not mentioned by respondents, but that may be because managers, not drivers, responded to the survey.

The earthquake motivated only 15% of the CPP survey respondents to prepare plans for future earthquakes. Because the survey was conducted in July and August 1994, there had been some time for these firms to develop these plans after they recovered from the earthquake. The most common type of plan created was an emergency preparedness plan for the firm (5%), followed by a communications plan (4%). Operations management plans and arrangements with customers were mentioned by a handful of respondents. A number of respondents thought about or intended to prepare plans, but had not done so. One respondent said: "I pray harder."

TABLE 2 Responses to Survey Questions: Were your cost/revenues different from what you would have expected if the earthquake did not occur? What was the percent change?

	First quarter		Second quarter	
	Revenue (n=148)	Cost (n=138)	Revenue (n=149)	Cost (n=157)
Mean	–0.20%	+3.53%	+0.80%	+0.75%
Standard deviation	14.2	11.8	5.2	8.8
Median	0%	0%	0%	0%
Range	–60% to +50%	–50% to +40%	–40% to +50%	–30% to +37%

IMPACTS ON REVENUE AND COSTS

The revenue and cost impacts of the earthquake reflect effects that are quite complex. Increased costs, such as wages or fuel, were expected, but firms also incurred increases or decreases in revenues, depending on their circumstances.

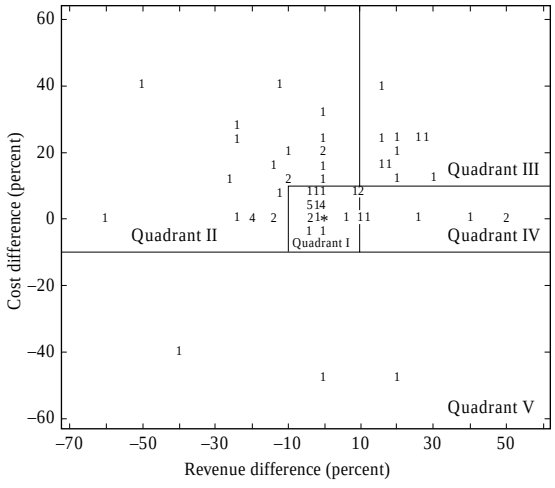
The CPP survey asked CEOs or CFOs of each company for estimates of cost and revenue impacts for the first and second quarters of 1994. The mean size of the firms in the survey was 32 employees, and their mean first quarter sales level was $837,534. Table 2 summarizes the impact of the earthquake on revenues and costs. Respondents were asked to estimate the change in total revenues and costs over what was expected if the earthquake had not occurred. This technique relied on the respondent's judgment to control for non-earthquake-related fluctuations in the economy and other disruptions such as the May 1994 Teamster's strike. Respondents provided a good response rate on these questions and did not report having difficulty in estimating earthquake impacts apart from other factors. The result shows a modest overall impact on trucking operations in Los Angeles County. The only change larger than 1%, either positive or negative, was an mean cost increase of 3.5% in the first quarter. The large standard deviation indicates the impacts experienced by individual firms varied widely. The median change in costs and revenues was 0% for both quarters.

The average and median data indicate overall impacts but mask larger impacts felt by a smaller group of firms. A 15% average decrease in first quarter revenues was experienced by 35 firms, while 23 firms had revenue *increases* averaging 22%. Revenue decreases are associated with lower levels of operations or less customer demand. On the other hand, the earthquake created an immediate need for additional trucking activities as firms relocated or changed production strategies, creating additional revenues for some respondents.

The average first quarter increase in costs for the 48 firms that reported an increase was 13%, a substantial impact for those firms. However, some cost increases resulted from a higher business volume. Five firms reported cost decreases averaging 30% (presumably because of scaled-back operations).

Figure 5 plots first quarter revenue and cost data to provide a better picture of the distribution and combinations of cost and revenue impacts. The data is grouped into five quadrants that represent different combinations of revenue and cost impacts. Quadrant I contains the majority of firms (93 of 135), with cost or revenue changes within plus or minus 10%. Quadrant II contains 24 firms that experienced more significant negative impacts—through increases in cost, decreases in revenue, or both. Quadrant III contains firms that had revenue increases and commensurate increases in costs. Quadrant IV includes five firms that had rev-

FIGURE 5 Plot of Revenue and Cost Impacts: First Quarter



Key: # indicates number of observations; * = 70 observations

TABLE 3 Kendall's Tau Rank Correlations of Revenue and Cost Impacts: First Quarter

	Revenue	Cost
Exposure	0.06	0.14**
Impact	–0.004	0.09*
Employees	–0.10*	0.11*
Sales	0.07	0.07
Shake	–0.05	0.10*

* Significant at 0.10 level
** Significant at 0.05 level

enue increases with no increase in costs, perhaps as the result of more efficiently using their capital and labor. Finally, Quadrant V contains a few firms that had large cost decreases. The plot reinforces the findings that most firms had small impacts and that the number of firms that were worse off was modest—24 firms in quadrant II.

We expected that the first quarter financial impact would be correlated to a variety of descriptors of exposure, impact, and firm characteristics. Table 3 shows Kendall's tau rank correlations for these variables with the percentage revenue change (REVENUE) and the percentage cost change (COST).

Only one significant relationship existed regarding revenues. Larger firms (as measured by number of employees) had a significantly greater decrease in revenues, perhaps because of differences in impacts on their customer base (@ $p<.1$). The correlation between EXPOSURE and REVENUE produced a positive sign but was not significant, reflecting the stimulating effect of the earthquake for some firms.

The impact on costs was more predictable. The relationships between COST and EXPOSURE, and COST and IMPACT, are positive and significant. Exposure to disrupted facilities is associated with cost increases, as is reported impacts on operations. Number of employees and proximity to ground shaking (SHAKE) are also positively and significantly related to COST.

Financial impacts were also expected to vary by type of trucking firm. Table 4 summarizes REVENUE and COST for each of the three types of trucking firms. Intra- and interstate truckers had the largest decline in revenue and the only cost increase that was not associated with greater revenue. The decline in revenue appears to have resulted from short-term disruption of shipping activities rather than a slowing of economic activity in the region. This sector has a greater probability of using the I-5 for north/south access out of the region and may have been more affected for that reason.

Couriers had virtually no change in revenues and a decrease in costs. Their greater reliance on local streets may have made them less affected by the earthquake, but clear reasons for the decrease were not identified. Movers, as one would expect, had a larger increase in revenues (because of greater moving activity) and lesser increases in costs. No movers reported revenue decreases. However, none of these differences are statistically significant ($p<.05$) because of the large variation in responses and the low representation of couriers and movers.

The CPP survey asked respondents to rate the most important factors in the changes in revenues and costs. Table 5 summarizes the top four factors in revenue and cost impacts. Business volume increases and decreases were the top responses on the revenue side, while labor and fuel costs were the dominant cost impacts.

When the first quarter revenue impact responses were weighted by the respondents' rank of importance there was no difference in rank order.[2] In the second quarter, increased business volume

[2] Unweighted tallies added together the responses for each category regardless of whether they were ranked first, second, third, or fourth in order of importance. Weighted tallies assigned a weight of 3 to the most important reason, 2 to the second most important reason, and 1 to the third most important reason.

TABLE 4 Mean Revenue and Cost Change by Trucking Firm Type: First Quarter

	Revenue		Cost	
	Mean	Standard deviation	Mean	Standard deviation
Overall sample	–0.2%	14.2	3.5%	11.8
Couriers (n=27)	0.3%	10.9	–3.4%	16.1
Intra- and interstate truckers (n=116)	–2.9%	12.9	4.7%	10.4
Movers (n=21)	12.5%	17.1	5.7%	11.5

TABLE 5 Responses to Survey Question: What were the main components of the change of costs/revenues in the first quarter?

	Revenue	Cost
Most frequent	Decreased business volume (44 responses)	Labor costs (57 responses)
Second most frequent	Increased business volume (22 responses)	Fuel costs (50 responses)
Third most frequent	Storage of goods (8 responses)	Vehicle maintenance (7 responses)
Fourth most frequent	Packaging (1 response)	Repair equipment (6 responses)

was the most important reason for a change in revenues. Respondents did not identify many revenue impacts that we initially hypothesized might have occurred: surcharges for additional mileage, changes in prices, penalties for late deliveries, or earthquake-related insurance or Federal Emergency Management Administration payouts.

The order of the first quarter *cost* responses did not change when they were weighted, and were in the same order for the second quarter of 1994. The primary impacts are related to costs of sales (e.g., delivering goods) rather than costs of operations (e.g., running the company). Increased costs for rent, insurance, vehicle rental, and telephone and/or communications did not appear in the responses. In addition, facility or equipment damage was not a major impact.

An additional check on possible impacts on goods movement can be made by examining the consumer price index (CPI) for the region, both overall and in the various sectors affected most strongly by goods movement (U.S. Department of Labor 1994). If large cost increases occurred or shortages existed, one might see a higher rate of inflation in these costs. A multitude of factors affect CPI trends, so one cannot discern the effect of the earthquake from other economic variables without detailed econometric modeling, but the results show what did not happen: there was no post-earthquake spike in either the overall CPI for Los Angeles or the transportation or food indexes. This reinforces the survey findings that cost impacts and the impacts of late or delayed deliveries were relatively modest.

COMPARISONS WITH THE LOMA PRIETA EARTHQUAKE

Hansen and Sutter (1990) studied the impact of the Loma Prieta earthquake on Bay Area truckers. Their survey was the basis for the design of the CIC survey, so comparisons can be made between the two earthquakes. As mentioned previously, the comparisons must be considered exploratory because the Loma Prieta results are based on a small sample (37 survey responses).[3]

Both surveys asked identical questions about impacts. The frequency of "moderate to severe" responses were similar for congestion delay, circuitous routing, overloaded telephone lines, and inefficient dispatching (all within eight percentage points). The major difference was that Los Angeles trucking companies cited increased business more frequently—33% versus 8%. The type of disruption created by the Northridge earthquake seems to have created greater needs to move and ship goods as firms resumed their operations.

The Loma Prieta and CIC surveys also asked about response strategies. The Loma Prieta survey simply asked whether a strategy was used, while the CIC survey asked for a rating on how severe the action was. We combined CIC responses of "small," "moderate," and "severe" to compare with the Loma Prieta results. The results should be interpreted with caution because of potential differences in meaning of these categories. Table 6 shows that the most frequent responses were similar.

The Northridge earthquake respondents more frequently used response strategies in part because the geographic area of the CIC sample was smaller, so respondents were more likely to be close to

[3] Drawing the sample from CTA membership probably underrepresents small firms. It is also important to note that the Loma Prieta survey covers the region, while the CIC and CPP surveys are based on Los Angeles County only.

TABLE 6 Comparison of Affirmative Responses to CIC Research Survey and Hansen et al Questions: Please tell me if you took the action [I will read] after the earthquake.

Northridge earthquake (CIC)			Loma Prieta earthquake (Hanson et al)		
Response	Initial	Still in effect	Response	Initial	Still in effect
Rerouted to avoid congestion	81%	5%	Rerouted to avoid congestion	57%	37%
Rescheduled to avoid congestion	69%	4%	Rescheduled to avoid congestion	46%	22%
Increased use of driver overtime	55%	5%	Increased use of driver overtime	38%	19%
Reduced frequency of delivery and pickup	38%	1%	Stopped service to certain areas	38%	0%
Increased truck load through consolidation	29%	4%	Reduced frequency of delivery and pickup	24%	11%

the earthquake. The striking difference, however, is that very few Northridge earthquake respondents were still using response strategies four months after the earthquake, unlike Loma Prieta earthquake respondents. Normal (or near normal) traffic operations were restored much faster following the Northridge earthquake.

The Loma Prieta and CPP surveys asked cost impact questions a bit differently, so precise comparisons cannot be made. The Loma Prieta study found that the mean cost impact one month after the quake was an increase of 7.1%. The CPP survey found a 3.5% cost increase for the first quarter of 1995, which included 2½ months of post-earthquake conditions. It appears that the short-term cost impacts were roughly on the same order of magnitude. However, the longer lasting effects of the Loma Prieta earthquake (unmeasured in that survey) could mean that overall cost impacts were greater.

There are important differences in the revenue side. Loma Prieta truckers reported a revenue decrease of 5.3%, while the CPP survey found a revenue decrease of 0.2% for the first quarter. This larger revenue loss suggests that more extensive business closures occurred, or that inaccessibility prevented deliveries. In the Northridge case, increases in business by some sectors counteracted the loss experienced by others.

Despite these differences, it appears that the impacts on revenues and costs were modest in both cases. Perhaps this similarity exists because both earthquakes primarily affected highway and arterial movement. In both cases, rerouting and rescheduling strategies were used to avoid damaged facilities, and costs and revenue impacts were relatively contained.

CONCLUSIONS

The Northridge earthquake tested the capacity and flexibility of Southern California's highway-based goods movement system, as well as the ability of public agencies and trucking firms to respond to rapidly changing conditions. By most measures, the systems and the institutions passed the test. The rapid restoration of transportation capacity was a key factor, making longer term strategies such as mode shifting unnecessary, and it moderated the financial impacts. There was considerable variability in the level of impact among individual firms, and those firms demonstrated ingenuity in devising response strategies under stressful, rapidly changing conditions.

What then does this analysis indicate about possible disruptions from future earthquakes? We suggest caution in drawing broad conclusions based on these results. The most obvious consideration is that the Northridge earthquake was not of a magnitude as great as is possible in Southern California. Even if a future earthquake was of a similar magnitude, however, it could bring different results.

An earthquake that affected key nonhighway goods movement facilities, such as a port or airport, major pipelines, or key rail lines might have a much larger impact. The Northridge earthquake affected the goods movement mode with *the greatest level of flexibility and redundancy.* As well, an earthquake epicenter closer to the region's core goods movement facilities would likely be more disruptive. For example, the Newport-Inglewood fault, which traverses central Los Angeles, is a major threat to the region's highway, airport, port, rail, and pipeline facilities.

The earthquake provoked little planning and preparedness activities among trucking companies. The tone of the interviews suggested that the earthquake was one of many disruptions that trucking firms experienced over the previous five years. It was seen as one of a series of operational challenges, rather than an event that permanently shifted perceptions. Trucking companies have continual experience in dealing with natural and manmade disruptions in Los Angeles. However, the ability of public and private actors to coordinate mode-switching strategies for goods movement was largely untested. Significant constraints may exist in that area.

Natural disasters place special requirements on researchers and public agencies. Restoring mobility is of chief importance, but survey research must be immediate as well. The surveyors in this study benefited from respondents' good will, partly due to a feeling of community cooperation after the earthquake and partly due to satisfaction with Caltrans' quick restoration of mobility. However, the experience of the earthquake is short-lived; immediate data collection is needed to capture these effects. Pre-arranged research protocols might include strategies for collecting data, standards for comparing results from different disasters, and coordination between public agencies and research institutions.

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